

**U. S. DEPARTMENT OF ENERGY  
FIELD WORK PROPOSAL**

1. WORK PROPOSAL NO.: <div style="text-align: center;">2421.1</div>	2. REVISION NO.:	3. DATE PREPARED: <div style="text-align: center;">03-15-07</div>	3a. CONTRACTOR NO.: <div style="text-align: center;">52210</div>
4. WORK PROPOSAL TITLE: Detector R&D			
5. BUDGET & REPORTING CODE: KA-15-03-02	6. WORK PROPOSAL TERM: Begin:                      End:	7. IS THIS WORK PACKAGE INCLUDED IN THE INST. PLAN? <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	7a. PRINCIPAL INVESTIGATORS: Wagner, R. Byrum, K.
8. HEADQUARTERS/OPERATIONS OFC PROGRAM MANAGER: Staffin, R.                      No. 301-903-3624	11. HEADQUARTERS ORGANIZATION: High Energy Physics		14. DOE ORG. CODE: SC
9. DOE FIELD ORGANIZATION WORK PROPOSAL REVIEWER:	12. DOE FIELD ORGANIZATION: Chicago		15. DOE ORG. CODE: CH
10. CONTRACTOR WORK PROPOSAL MANAGER: Weerts, H.J.                      No. 630-252-8831	13. CONTRACTOR NAME: UChicago Argonne, LLC		16. CODE: 12
17. IS THIS PROPOSAL TO DO WORK THAT INCLUDES A SECURITY INTEREST? <span style="float: right;"><input type="checkbox"/> YES      <input checked="" type="checkbox"/> NO</span>			
18. WORK PROPOSAL DESCRIPTION (Approach, anticipated benefit in 200 words or less):  <div style="margin-top: 20px;"> <p>This task comprises the invention, development, and testing of new detector technology for high energy physics and particle astrophysics. For the most part, our detector development is aimed at detector types needed for specific experiments, either approved experiments in the early stages of design, or potential new projects that are not yet established.</p> </div>			
19. CONTRACTOR WORK PROPOSAL MANAGER:  <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;">   <hr style="width: 100%;"/> </div> <div style="text-align: center;"> 03-15-07  <hr style="width: 100%;"/> </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <span>SIGNATURE</span> <span>DATE</span> </div>		20. OPERATIONS OFFICE REVIEW OFFICIAL:  <div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;"> <hr style="width: 100%;"/> </div> <div style="text-align: center;"> 03-15-07  <hr style="width: 100%;"/> </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <span>SIGNATURE</span> <span>DATE</span> </div>	
21. DETAIL ATTACHMENTS: (See specific attachments.)			
<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%;"> <input type="checkbox"/> a. Facility requirements  <input type="checkbox"/> b. Publications  <input checked="" type="checkbox"/> c. Purpose (mandatory)  <input type="checkbox"/> d. Background </div> <div style="width: 50%;"> <input checked="" type="checkbox"/> e. Approach  <input checked="" type="checkbox"/> f. Technical progress  <input checked="" type="checkbox"/> g. Future accomplishments  <input checked="" type="checkbox"/> h. Relationships to other projects </div> <div style="width: 50%;"> <input type="checkbox"/> i. NEPA requirements  <input checked="" type="checkbox"/> j. Milestones  <input type="checkbox"/> k. Deliverables  <input type="checkbox"/> l. Performance Measures/Expectations </div> <div style="width: 50%;"> <input type="checkbox"/> m. ES&amp;H considerations  <input type="checkbox"/> n. Human/Animal Subjects  <input type="checkbox"/> o. Security requirements  <input checked="" type="checkbox"/> p. Other (specify) </div> </div>			

**WORK PROPOSAL REQUIREMENTS FOR OPERATING/EQUIPMENT  
OBLIGATIONS AND COST**

CONTRACTOR NAME UChicago Argonne, LLC		WORK PROPOSAL NO. 2421.1		REVISION NO.		CONTRACTOR NO. 52210		DATE PREPARED 01/30/2007	
21. STAFFING (in staff years)		PRIOR YEARS	FY2007	FY2008	FY2009		FY2010	FY2011	TOTAL TO COMPLETE
				ESTIMATE	REQUEST	AUTHORIZED			
a. Scientific .....			3.4	5.7	7.0		0.0	0.0	
b. Other Direct .....			0.9	0.9	0.9		0.0	0.0	
c. Technical Services* .....			0.1	0.1	0.1		0.0	0.0	
d. Total Direct .....			4.4	6.7	8.0		0.0	0.0	
23. OBLIGATIONS AND COSTS (in thousands)									
a. Total Obligations .....			1018	1487	1977		0	0	
b. Total Costs .....			1002	1462	1950		0	0	
24. EQUIPMENT (in thousands)									
a. Equipment Obligations .....			0	0	0		0	0	
b. Equipment Costs .....			0	0	0		0	0	
25. MILESTONE SCHEDULE (Tasks)		FY2009 DOLLARS				PROPOSED SCHEDULE	AUTHORIZED SCHEDULE		
		PROPOSED		AUTHORIZED					
26. REPORTING REQUIREMENTS									

\* Technical services staffing includes ANL support divisions' scientific effort.

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**A. R&D for Pico-Second Readout and Electronics for TOF and PET applications**

Collaborative efforts between Argonne National Laboratory, the University of Chicago Enrico Fermi Institute, and the University of Chicago Radiology Department have started to develop instrumentation to perform ultra-fast time-of-flight measurements, and to apply techniques of HEP for particle detectors, fast electronics, data acquisition, and 'end-to-end' simulation of time-of-flight measurements in biomedical imaging. We consider this as both an opportunity to probe fundamental physics, and also as a technical challenge, with potentially major impact on medical and industrial diagnostics. Resources for this effort come from DOE base funds, DOE ADR funds, Univ. of Chicago funds, and LDRD funds.

a) FY 2006-2007 Accomplishments: We have begun to develop the electronics to read out a Micro-Channel Plate photon sensing device. We have completed construction of a new laser laboratory facility designed to test timing performance and perform characterization studies of photon sensing devices. We have begun a program of characterizing the timing properties of Micro-Channel Plates built specifically for us by Burle Industries. We have collaborated with Burle to specify the electrical characterization of facets of this device. We have begun design work with the University of Chicago on two custom ASICs chips for time-to-digital conversion with a resolution of 1 ps. We have submitted a proposal for an Initiative for the continued development of this project jointly to DOE and NSF. In the proposal, we have requested funds for ANL for one engineer working full time on the continued development on one of the ASICs required for readout electronics. We have also requested funds for one postdoc, to carry out this experimental program while focusing and preparing for a next-generation TOF detector to be applied in an upgrade at the LHC or for the future International Linear Collider.

b) FY 2008/2009 Plans: We will continue to develop the front-end DAQ ASIC chip and begin design of a data acquisition system. We will continue our program of characterizing and studying photon sensors for development of 1 ps resolution TOF detectors.

**B. R&D for Silicon Photo-multiplier Detector applications**

We have begun R&D using silicon photo-multipliers (SiPM), a novel photo-detector fabricated from silicon. The devices have many interesting performance aspects: a photo-electron gain of  $\sim 10^6$  at only  $\sim 40$ - $50$  V; small size, of order  $1 \text{ mm}^2$ ; almost no sensitivity to magnetic fields; and low cost,  $\sim \$100/\text{channel}$ . For some applications, they have the potential to

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replace conventional photo-multiplier tubes. Furthermore, their unique features offer possible applications that excluded the use of photo-multipliers in the past, such as low cost, small size, and low operating voltage. Possible applications include detectors for high-energy physics, x-ray detectors for experiments with synchrotron light sources (such as the Argonne Advanced Light Source), homeland security, telescope cameras for particle astrophysics applications, and Positron Emission Tomography (PET) scanners. The devices were first developed in R&D labs in Russia several years ago, and are now beginning to be produced commercially by several companies around the world.

In 2006 we received LDRD funding from Argonne to begin an inter-divisional R&D program to study the characteristics of the devices, and also to produce conceptual designs for these applications. In parallel, we have been working with scientists at the University of Chicago Medical School to study applications in PET. The work has engaged the electronics group in the HEP division at Argonne, working closely with the detector R&D to develop optimized front-end electronics instrumentation. While there are other groups around the world who are working in these areas, we are unique in our approach to studying possible applications with a high-level of integration with the electronics, and are positioning ourselves to become world leaders with this technology. We expect that this work will form the basis of a broad program that utilizes SiPMs for different applications.

a) FY 2006-2007 Accomplishments: We have procured samples from several sources, including several production runs from Russia, and Hamamatsu. We have configured a test stand with a "dark box" that contains an LED pulser and a filter wheel, interfaced to charge amplifiers and a readout system. We have begun studying different performance parameters, including: gain, linearity, noise, voltage dependencies, temperature effects, saturation, and dead-time. We have also begun measuring the response to different radioactive sources, including a positron-emitter. We expect that the basic performance test program will be completed in 2007, and that conceptual designs for different applications will have begun, including the design of the electronics. The work in this period is supported mostly from the ANL LDRD, with some support for scientists and engineers from discretionary base funding.

b) FY 2008 Plans: We will begin to procure larger numbers of samples from different commercial vendors, and continue with our characterization testing. Primary issues include uniformity, variations due to temperature and voltage, and the methods needed for calibration and stability. We will continue with our conceptual designs for different applications, including the design of the electronics. This work will be primarily supported from

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the second year of the ANL LDRD, again with some support from discretionary base funding for effort. We would like to pursue the development of a prototype detector for a new telescope array for particle astrophysics, as well as some of the other possible applications. It is for these activities that we seek additional base funding support through this FWP.

c) FY 2009 Plans: We will continue to develop the detector and electronics for the telescope camera in this period, as well as other applications depending on funding. We intend to test the prototype camera using the TrICE telescope (Track-Imaging Cherenkov Experiment), located at Argonne. This development is strategic and timely as the astrophysics community considers the design and development of the next generation of ground-based gamma-ray telescopes.

### C. Radar Detection of Cosmic Rays

Studies of cosmic rays are always statistics limited at the highest energies, due to the costs of the large areas needed for detection. Even the world's largest cosmic ray detector, the Pierre Auger Observatory, only expects to detect a few cosmic ray neutrinos per year. If the detection cost per unit area could be reduced significantly with a new approach, then much larger areas could be covered. One new approach studied in the last year has been radar detection of cosmic rays, using distant TV stations as the broadcast signal and inexpensive receivers to detect the reflected signals. Reflections off airplanes and meteors and lightning are clearly observed, and fast signals consistent with cosmic ray showers have also been detected. To prove these fast signals are truly cosmic rays will require taking portable systems to a working air shower detector and look for coincidences. This is the plan for the next year, in addition to beam tests at electron accelerators on the Argonne site.

If cosmic ray detection with radar is proven, then interest around the world will grow quickly and R&D funds will be sought. In addition, this project has tremendous outreach possibilities and educational funding will be sought.